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CANNABIS USE AND ITS EFFECTS ON HEALTH, EDUCATION AND LABOR MARKET SUCCESS

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Cannabis Use and Its Effects on Health, Education and Labor Market Success

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Abstract

Cannabis is the most popular illegal drug. Its legal status is typically justified on the grounds that cannabis use has harmful consequences. Empirically investigating this issue has been a fertile topic for research in recent times. We provide an overview of this literature, focusing on studies which seek to establish the causal effect of cannabis use on health, education and labor market success. We conclude that there do not appear to be serious harmful health effects of moderate cannabis use. Nevertheless, there is evidence of reduced mental well-being for heavy users who are susceptible to mental health problems. While there is robust evidence that early cannabis use reduces educational attainment, there remains substantial uncertainty as to whether using cannabis has adverse labor market effects.

Keywords: cannabis use, health, education, labor market

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1 Introduction

Cannabis is the most popular illegal drug. Between 2.8 and 5.0 percent of the world's population aged 15-64 uses cannabis at least once a year. This corresponds to between 130 and 230 million people (United-Nations (2013)).[1] The sheer number of cannabis users is surprising given that cannabis supply and distribution is prohibited globally, and use is a criminal offense in most nations. The legal regime governing cannabis use is less strict in some countries. For example, the Netherlands have quasi-legalized cannabis use; in the US, several jurisdictions have made cannabis available for medical purposes ("medical marijuana") and since 2014 cannabis is legal in two US states (Colorado and Washington although at the federal level cannabis use is still prohibited). In some Australian states and territories, both growing cannabis for personal use and consuming cannabis has been reduced to a civil offense via decriminalization (Reuter (2010)). Jurisdictions which take a "soft" approach to cannabis are, however, the exception to the rule. By and large, those who use cannabis do so under the threat of criminal prosecution. This policy stance is typically justified on the grounds that cannabis use has harmful consequences. Empirically investigating this issue has been a fertile topic for research in recent times. The purpose of this paper is to review the evidence base accumulated to date. We highlight the contributions from the economics literature. A distinguishing feature of this literature is that it seeks to determine the causal nature of the relationship between cannabis use and its potential consequences.

A key concern voiced in policy debates on cannabis is that cannabis use has harmful health effects. And while many studies in the epidemiology and medical literature report a negative association between cannabis use and health, a causal relationship running from cannabis use to poor health is not the only possible explanations for this correlation. Two alternative explanations exist. First, there may be common determinants of both cannabis use and poor health that have not been accounted for. This case is often referred to as spurious correlation because there is no direct relationship between cannabis use and health, only an indirect one that operates via the common (unobserved) determinants. The second alternative explanation is that there is a causal relationship, but it runs from poor health to cannabis use. For example, a cancer patient undergoing chemotherapy may treat their nausea with cannabis. This explanation is called reverse causality. Distinguishing between these three alternative explanations is necessary in order to develop policies which are effective at achieving their goal. Clearly, reduced cannabis use will lead to an improvement in health only if the alternative explanations of spurious correlation and reverse causality can be ruled out. Herein lies the significance of the contributions from economics.

While the debate about cannabis often focuses on its direct health effects, cannabis use may also have indirect health effects. For example, cannabis use may adversely impact on educational attainment or labor market success. Previous research has found that that both educational attainment and income are important determinants of health outcomes. Consequently, if cannabis use impacts these outcomes, it will indirectly impact on health. For this reason we discuss studies that investigate the educational and labor market consequences of cannabis use in addition to those that analyze the health consequences. We do not, however, survey the contributions made by economists on the interaction between drug policy and drug use. Excellent surveys on this topic have been provided by MacDonald (2004), Pudney (2010), and Caulkins et al. (2012).[2] Similarly, we do not survey studies on the "stepping-stone" or "gateway" hypothesis, which posits that cannabis use leads to use of hard drugs such as cocaine or heroine. A gateway effect could exacerbate potential effects of cannabis use through the use of other more dangerous drugs. However, as for example MacDonald (2004) indicates, empirical research suggests that the relation between early cannabis use and later hard drug use derives from association through unobserved characteristics rather than through a direct causal path.

Before we proceed to surveying the literature on the relationship between cannabis, health, education and labor market outcomes, we provide context in section 2 by discussing the various indicators of the prevalence of cannabis use and characterizing cannabis use in terms of intensity and dynamics of use. In section 3 we present and discuss a number of recent studies on the effects of cannabis use on physical health and mental health. In addition to the direct health effects, in section 4 we also consider indirect health effects that occur through the impact of cannabis use on education. In section 5 we consider the relationship between cannabis use and labor market success. Section 6 concludes.

2 Characteristics of cannabis use

2.1 Prevalence and intensity of cannabis use

Table 1 reports detailed information on the intensity of cannabis use distinguishing between lifetime use, last year use, last month use and daily use (in last month). There is substantial variation in each of these measures of use both across countries and within countries. The variation across countries is demonstrated by comparing Hungary, where just 8.5% of the population aged 15-64 have used cannabis in their lifetime, with the US where 42% of those aged 12 or older have used cannabis in their lifetime. The within-country variation is also large. In the Netherlands for example, 22.6% of the population aged 15 to 64 have used cannabis in their lifetime but only 5.4% have done so in the last year and 3.3% in the last month. Daily or almost daily use is relatively high in France, Spain and the US, but it is striking that in all other countries less than 1% of the population use cannabis on a daily basis. Apparently, cannabis use is not very addictive for a substantial part of the users (see Van Ours (2005) for details). Also, the numbers in Table 1 illustrate that although a substantial part of the population have used cannabis, the prevalence of heavy use in the population is quite low.

2.2 Dynamics in cannabis use

While the prevalence of past month or past year cannabis use is a commonly cited measure of the extent of its use, and one that is easily comparable to other measures of risky behavior or adverse outcomes, it is nonetheless a rather crude metric and one that that may be considered misleading for at least two reasons. First, cannabis use is concentrated amongst young individuals. It may therefore be argued that the prevalence of use in the population at risk of using (those aged 15-25 for example) is more informative about the extent of cannabis use than the prevalence in the population aged 15-64. The second reason that simple prevalence rates may be considered misleading is that this measure provides no information on lifetime trajectories and patterns of use in general, and harmful use in particular. Although a significant proportion of the population will have tried cannabis at some point in their life, many use for a short period only. Some use it on a regular basis but at low, recreational levels, akin to drinking a beer every now and then. Others will become long term heavy users. Moreover, it is widely believed that early onset of cannabis use has especially harmful effects on health and life outcomes. Therefore, in this section we provide cross-country information on the dynamics of cannabis use, including age of at first use and the duration of use.

Figure 1 shows typical patterns in the dynamics of cannabis use for a sample of Amsterdam residents (Van Ours (2005)), for individuals living in Australian households, and for individuals from the US interviewed in the National Longitudinal Survey of Youth 1997 (NLSY97). The information for Amsterdam and Australia related to individuals aged 25-50 when surveyed, while the NLSY97 data are on individuals who were 24-29 the last time they were surveyed. The top-left graph shows that people start using cannabis between age 15 and 25, with clear peaks at age 16, 18 and 20. If uptake has not occurred before age 25, it is very unlikely to occur later on in life. The top-right graph shows the cumulative starting probability, which increases between age 15 and 25 and then levels off at older ages at a prevalence of between 50 and 60 percent. The bottom-left graph shows that in Amsterdam and Australia about 20 percent of the cannabis users stop using within a year of starting. The bottom-right graph shows that many consumers stop using after a couple of years, but even 20 years after they started between 30 and 40 percent are still using cannabis. Based on these dynamics three groups of individuals can be distinguished, abstainers, experimentalists and persistent users some of whom are recreational users while others are addicts. It is noteworthy that despite having very different legal regimes governing cannabis use, these three countries exhibit very similar patterns in the dynamics of cannabis use.

3 Direct health effects of cannabis use

There has been no recorded case of mortality due to cannabis overdose and it was not until the 1990's that cannabis was first recognized as a drug of dependence (Roffman and Stephens (2006)).[3] Nevertheless, among inexperienced users and experienced users following heavy consumption, cannabis intoxication may result in anxiety, panic and psychotic symptoms.[4] Research has investigated the potential for cannabis use to impact on mortality and morbidity through road traffic accidents, and mental and physical health.

3.1 Physical health

The vast majority of what is known about the impact of cannabis on physical health comes from the epidemiology literature, with economists making only a small number of contributions. Epidemiological studies investigate the risk to physical health from acute use (cannabis intoxication) and from chronic use. In terms of acute use, the focus has been on the question of whether cannabis intoxication increases the risk of road traffic accidents.[5] Experimental studies based on driving simulators or driving courses tend to find that cannabis users compensate for impairment while intoxicated by driving more safely. Given that participants in the experiments are aware they are being observed and assessed, this line of research may not be very informative about the way cannabis impaired drivers actually drive while intoxicated, and hence the impact of cannabis use on the risk of road traffic accidents. The epidemiology literature views culpability and case controlled studies as providing better evidence on the risk of a traffic accident due to cannabis intoxication (Sewell et al. (2009)). Amongst the challenges faced by these studies, however, is that the relationship between blood serum THC levels and impairment is poorly understood.

Culpability studies assign drivers who have crashed according to their degree of responsibility for the crash, and then seek to determine whether cannabis use is more prevalent in the group of drivers culpable for crashes. In their review of the literature, Sewell et al. (2009) report contradictory findings from culpability studies. They identify measurement error in allocating individuals to the cannabis impaired versus non-impaired group as a significant issue in this literature.[6] As with culpability studies, case control studies use information from administrative databases on crashes involving a fatality and compare the prevalence of cannabis use amongst drivers injured or killed in traffic accidents with that in a suitably chosen control group. Studies of the impact of cannabis use on traffic accidents using the case control methodology have produced conflicting findings. As discussed in the assessment of this literature by Sewell et al. (2009), this may be attributable to weaknesses in the selection of controls, as well measurement errors associated with using the metabolite carboxy-THC, which is present in ones system days after the consumption of cannabis, to determine cannabis intoxication. In addition to the challenges presented for culpability and case control studies discussed above, there remains the issue of unobserved common founders that potentially determine both the decision to drive while intoxicated and the decision to use cannabis. This challenge is yet to be adequately addressed within the epidemiology literature.

A recent contribution from the economics literature takes a somewhat different approach to understanding the relationship between cannabis use and road traffic fatalities. Specifically, Anderson et al. (2013) investigate the impact of laws that legalize the use of cannabis for medical purposes on road traffic fatalities. They find that in the first full year after coming into effect, legalization is associated with an 8-11 percent decrease in road traffic fatalities. Importantly, the reduction is larger for fatalities involving alcohol.[7] They also show that legalization is associated with a reduction in the price of cannabis and a reduction in consumption of alcohol. As legalization of cannabis for medical purposes does not typically permit the use of cannabis in public, the authors suggest their results are consistent with consumption of cannabis at home being substituted for consumption of alcohol at bars and restaurants. Thus the reduction in road fatalities is due to a net reduction of driving while intoxicated by alcohol or cannabis rather than safer driving under the influence of cannabis compared to alcohol.

Studies investigating the physical health risks of chronic cannabis use are generally interested in its impact on diseases such as cancer and emphysema, which take many years to develop. As a consequence, they tend to focus on heavy long term use. Given that smoking is the typical mode of administration for cannabis use, one of the concerns about chronic cannabis use is that it may increase the risk of cancer of the lungs, upper respiratory tract, head and neck. The research from epidemiology on the effect of cannabis use on these cancers does not provide clear cut evidence with studies reporting mixed findings (Mehra et al. (2006); Hashibe et al. (2005)). The effect of cannabis use on the risk of emphysema has also been examined. For example, Tashkin (2001) followed individuals in the US over eight years and found that cannabis smoking did not increase the risk of emphysema. Similarly, no increased risk of emphysema was found in a group of heavy cannabis only smokers in New Zealand (Aldington et al. (2007)).

There are only a handful of studies in economics that investigate the impact of cannabis use on physical health. A key contribution of this small literature is that the studies tend to use techniques designed to tease out causal effects. Williams and Skeels (2006) use an Instrumental Variable (IV) approach to identify the causal effect of cannabis use on self assessed health status using data representative of the Australian non-institutionalized population, and accounting for endogenous cigarette smoking. They find that, after accounting for the effect of cigarette smoking, the probability of being in very good or excellent health is 8% lower amongst those who consumed cannabis in the past year compared to those who had not and 18% lower for those who reported weekly use. Van Ours and Williams (2012) use a discrete factor approach to account for selection into cannabis use in their investigation into the mental and physical health effects of cannabis consumption. Their set-up combines a bivariate mixed proportional hazard (BMPH) model for cannabis uptake and quitting with linear models for mental and physical health where unobserved heterogeneity for all four outcomes is drawn from a multivariate discrete distribution. Their results suggest that cannabis use reduces the physical well-being of men. Although statistically significant, the magnitude of the effect of using cannabis is found to be small. This suggests that while cannabis use does have a detrimental effect on overall health, the magnitude of this effect is not large for the typical user.

While the strength of the contributions from economics in this area is the attention given to distinguishing causality from correlation, it is important to acknowledge that one cannot "prove" causality. Each statistical technique used to identify a causal effect ultimately relies on an assumption that is untestable. Therefore, in evaluating the evidence contributed by the economic studies, one must consider the credibility of the assumptions employed to identify the causal effect. The two approaches used in the studies discussed above, IV and a bivariate proportional hazard model employing a discrete factor approach, are both commonly used in the relevant economics literature, and for this reason we provide a detailed discussion of identifying assumptions for these methods below.

The untestable identifying assumption for IV based strategies is that the set of instruments is validly excluded from the equation for the outcome of interest. In the paper by Williams and Skeels (2006), the instrument set consists of family structure, state policies relating to cannabis and cigarette use, and attitudinal variables. As noted by Dee and Evans (2003), the use of cross-sectional variation in policies that target substance use in order to identify the effect of substance use on outcomes of interest can be problematic if the policy variables themselves are correlated with unobserved state specific characteristics that also determine the outcomes of interest.

Unlike Instrumental Variables estimation, the bivariate mixed proportional hazard model (which uses the discrete factor approach to model unobserved heterogeneity) does not require exclusion restrictions in order to identify the causal effect of interest, and it is robust to misspecication of the functional form of the joint distribution of unobserved heterogeneity compared to methods that require parametric distributional assumptions. As discussed by Van Ours and Williams (2012), identification of their four equation system with correlated errors comes from the timing of events and the assumption of mixed proportional hazard rates in the cannabis dynamics part of the model, as well as distributional assumptions in the health production functions.[8] This needs to be considered in evaluating the findings of this study (and those based on this approach more generally). A further issue to considered for this paper is that, while the analysis accounts for endogeneity of cannabis arising through common unobserved confounders, the data used are not rich enough to account for the potential for reverse causality, as arises in the event that ill health leads to cannabis use. To the extent that reverse causality occurs, this paper will tend to overstate the impact of cannabis use on health.

3.2 Mental health

As with physical health, the majority of research on the relationship between cannabis use and psychological well-being has been contributed by the epidemiology literature. In fact, the number of epidemiology and medical studies in this area is so large that there are now quite a few overview studies that summarize the literature's main findings. The main findings in the overview studies are discussed below and summarized in Table 2.[9]

In a meta analysis, Degenhardt et al. (2003) find a modest but significant association between heavy use of cannabis and later depression. Arseneault et al. (2004)

report that cannabis use is neither a necessary nor a sufficient condition for the development of psychosis. Kalant (2004) conclude that for the relationship between cannabis use and psychiatric problems, there is more evidence for causality than for reverse causality. However, while Macleod et al. (2004) find evidence of association between cannabis use and psychosocial harm, they conclude that the causal nature of the relationship is far from clear. Henquet et al. (2005) find there is a causal effect of cannabis use on schizophrenia but that it is not very large and the mechanism underlying the causal effect is unclear. Both Semple et al. (2005) and Hall (2006) conclude that there is an association between psychosis and cannabis use but whether there is a causal relationship remains unclear and controversial. Moore et al. (2007) perform a meta-analysis of the longitudinal studies investigating the impact of cannabis use on psychotic symptoms and disorders. They report a pooled odds ratio for psychotic symptoms or disorders in those who had ever used cannabis of 1.4 times the risk of someone who had never used cannabis. Nonetheless, there has been much debate as to whether the findings of this literature reflect a causal relationship between cannabis use and psychotic symptoms. Concerning depression and cannabis use Hall and Degenhardt (2009) conclude that the epidemiological research on this association is mixed. Finally, both McLaren et al. (2010) and Werb et al. (2010) find there is insufficient evidence to conclude that a causal effect from cannabis use to psychosis exists.

In epidemiological studies based on longitudinal data, the issue of reverse causality is addressed by only considering those for whom cannabis use preceded the onset of mental health problems, or by controlling for pre-existing mental health problems in studying the contemporaneous impact of cannabis use on mental health. These studies then attempt to identify the causal effect of cannabis use by controlling for observed factors that may be a source of confounding (for example, Fergusson and Horwood (1997)).[10] However, as noted by Pudney (2010), the potential for unobserved common confounding factors makes inference regarding the causal impact of cannabis use difficult.

Studies from economics on the question of whether using cannabis reduces psychological well-being recognize and seek to address the issue of omitted confounding factors (see Table 3 panel *a* for an overview). Van Ours and Williams (2011) and Van Ours and Williams (2012) use cross-sectional data from Australia and the Netherlands respectively to study the impact of cannabis use on mental health. Even though they have cross-sectional data, using retrospective questions of the age of uptake of cannabis and sometimes the age of last use, they are able to model cannabis use dynamics. Van Ours and Williams (2011) account for common unobserved factors affecting mental health and cannabis consumption by modeling mental health jointly with the dynamics of cannabis use and employing the discrete factor approach. They find that using cannabis increases the likelihood of mental health problems, with current use having a larger effect than past use. The estimates suggest a dose response relationship between the frequency of recent cannabis use and the probability of currently experiencing a mental health problem. As discussed above, Van Ours and Williams (2012) account for selection into cannabis use and shared frailties in mental and physical health using a bivariate mixed proportional hazard model for cannabis use dynamics and linear equations for mental and physical health combined with the discrete factor approach o accounting for correlated unobserved heterogeneity. Their results suggest that cannabis use reduces the mental well-being of men and women. Although statistically significant, the magnitude of the effect of using cannabis on mental health is found to be small.

In order to address the issue of reverse causality, longitudinal information about the age of onset of mental health problems and cannabis uptake is required. The only paper in the economics literature with access to sufficiently rich data to address the potential for reverse causality is by Van Ours et al. (2013). This study uses the Christchurch Health and Development Study, a thirty year follow up study of a birth cohort born in Christchurch New Zealand to investigate the relationship between the uptake of regular cannabis use and the onset of suicidal ideation. In order to account for reverse causality as well as unobserved common confounders the authors adopt a fully simultaneous BMPH framework. Specifically, in addition to cannabis use entering the hazard rate for suicidal ideation and suicidal ideation entering the hazard rate for cannabis uptake, the unobserved heterogeneity terms in the hazard rates are assumed to be drawn from a bivariate discrete distribution. The results suggest that intensive cannabis use – at least several times per week – leads to a higher transition rate into suicidal ideation for males who are vulnerable to suicidal ideation. Importantly, they find no evidence that suicidal ideation leads to regular cannabis use for either males or females. As with the earlier studies that use the BMPH approach, the identification of causal effects in this study is based on the timing of events and the assumption of proportional hazards.

Overall, the three studies from economics suggest that cannabis use has a negative effect on psychological well-being, with the magnitude of the effect generally greater at higher intensities of use. This finding is robust to accounting for reverse causality, common time invariant confounders and shared frailties between mental and physical health.

4 Cannabis use and education

There is substantial evidence from the epidemiology literature that early cannabis use is associated with lower levels of education (Macleod et al. (2004), Lynskey and Hall (2000)). However, while longitudinal prospective studies are able to rule out academic failure causing cannabis use, the issue of omitted confounding common factors remains a potential threat to a causal interpretation. For example, conduct problems is an important risk factor for cannabis use as well as reduced educational success (Fergusson et al. (1993); Pedersen et al. (2001)). Failing to account for the impact of conduct problems on educational success leads to endogeneity of cannabis use. As with the impact of cannabis use on physical and mental health, this issue of the potential for endogeneity of cannabis use is addressed in the economics literature on cannabis use and educational attainment (see panel *b* of Table 3).[11]

The method of Instrumental Variables (IV) is used to account for the endogeneity of cannabis use when examining its impact on education by Register et al. (2001), Roebuck et al. (2004) and Chatterji (2006). Using data on males from the NLSY, Register et al. (2001) examine the impact of drug use by the age of 18 on the number of years of education completed. They find that on average, male adolescent drug use is associated with a reduction of around 1 year in educational attainment, where this result is driven by the whites in the sample. Roebuck et al. (2004) use two waves from the National Household Survey on Drug Abuse (1997 and 1998) to study the impact of cannabis use on high-school dropout, distinguishing between chronic cannabis use (weekly or more) and non-chronic cannabis use (less than weekly). Their results (from estimating univariate probit models) suggest that chronic cannabis use increases the probability of dropout by between 1.34 and 1.97 percentage points while non-chronic cannabis use reduces it by between 0 and 0.07 percentage points.[12] Chatterji (2006) exploits the unusually rich National Education Longitudinal Study to examine the impact of past month cannabis use in 10^{th} and 12^{th} grade on subsequent years of education completed. The IV estimates of the impact of cannabis use are generally negative, statistically indistinguishable from zero, and not statistically different from the OLS estimates. Based on the OLS estimates, the author concludes that cannabis use in 10th grade reduces educational attainment by around 0.2 of a year, and cannabis use in 12th grade reduces it by 0.3 of a year. As discussed previously, identification of causal effects using the IV estimator rests on the untestable assumption that the set of instruments is validly excluded from the equation for the outcome of interest.[13]

Van Ours and Williams (2009) address the question of whether cannabis uptake is more harmful for education outcomes at some ages compared to others, and whether the effect differs across gender. The authors use individual level data from Australia to estimate a bivariate mixed proportional hazard model for starting cannabis use and leaving education. The endogeneity of cannabis use arising from common unobserved variables is addressed using the discrete factor approach to modeling the joint distribution of unobserved heterogeneity determining the hazard for leaving education and the hazard for starting cannabis use. In terms of the impact of cannabis use on school leaving, they find that initiating cannabis use at younger ages leads to larger increases in the rate of school leaving compared to initiation into cannabis use at older ages. In addition to accounting for endogeneity arising from common unobserved confounders, the authors also investigate the potential for reverse causality. Their findings are robust to accounting for this additional source of endogeneity.[14] As discussed above, identification of causal effects in the BMPH model relies on the timing of events (school leaving, cannabis uptake) as well as the (untestable) assumption of proportional hazard rates for school leaving and cannabis uptake, and this caveat should be borne in mind in interpreting and assessing the findings.

Rather than using a statistical approach to account for the endogeneity of cannabis use arising from common confounders, McCaffrey et al. (2010) attempt to directly account for all factors systematically related to cannabis use that may also impact on education in their analysis of the impact of heavy and persistent cannabis use on high-school dropout. Using data from a panel study of 7th grade students from South Dakota between 1997 and 2004, the authors find that the positive association between cannabis use and dropout is to a large extent due to differences in characteristics and behaviors measured before cannabis use started. The identifying assumption in this analysis is that after conditioning on observable, there exist no unobservable common confounders. This assumption is untestable, and this caveat should be kept in mind when assessing the interpreting this study's findings (Pudney (2010).[15]

5 Cannabis use and labor market success

A significant contribution of the early economic studies on the relationship between drug use and labor market success is their formalization of the behavioral relationship between these outcomes and recognition of the potential endogeneity of the decision to use drugs. Two separate avenues through which endogeneity of drug use may arise were identified: reverse causality and omitted variables. Reverse causality occurs because a large component of a person's income is labor market earnings. Therefore, an increase in income (via an increase in wages or employment) will lead to a greater demand for drugs (if drug use is a normal good). A second reason to suspect that drug use may not be exogenous to labor market outcomes in a statistical sense is omitted variables.

An example of an important unobserved determinant of wages or employment that also influences the decision to use drugs is an individual's health status. Individuals who are in worse health may be more likely to use drugs to address their symptoms. Those in ill health may also be more likely to choose jobs that are less demanding and more flexible, trading off these attributes for lower wages. This may give rise to a negative correlation between drug use and wages even if drug use is not causally related to wages. Similarly, individuals with strong preferences for leisure may also be more likely to use drugs if drug use and leisure are complements in the production of euphoria. Such a relationship would produce a negative correlation between drug use and labor supply even in the absence of a causal effect of drug use on labor supply.

The first wave of studies into the impact of drug use on wages and employment use an Instrumental Variable approach to estimating causal effects. An overview of the main characteristics of the first wave of studies in which the health effects are measured indirectly is provided in Panel $c1$ of Table 3. Three of these studies draw on data on 18-27 year olds from the 1984 cross-section of the National Longitudinal Survey of Youth (NLSY) and all three studies found evidence that, rather than reduce wages as theory predicts, drug use increases wages.

The estimated magnitudes of the wage effects from these studies are quite large. For example, Kaestner (1991) estimates that males who have tried cannabis earn 18% more than otherwise similar males who have not tried cannabis, Register and Williams (1992) estimate that using cannabis on one more occasion per month increases hourly wages by 5%, and Gill and Michaels (1992) find that drug users earn about 4% more per hour than non-users. Register and Williams (1992) and Gill and Michaels (1992) also report results that show that the probability of being employed is reduced by cannabis use and drug use, respectively. It is noteworthy that very little (and sometimes no) discussion of identifying assumptions is found in these early studies, and many of the exclusion restrictions could be considered questionable.[16] Given this, and the current state of knowledge regarding the importance of the validity assumption and the performance of IV when instruments are weak, one might reasonably view the findings of these early papers with caution. A more cautious interpretation of the evidence regarding cannabis use and labor market outcomes is also suggested by Kaestner (1994a,b), who concludes that drug use does not have a systematic impact on labor supply or wages.

The counter-intuitive and inconsistent findings of the above studies motivated a second wave of economic research into the impact of drug use on wages and labor supply. Panel $c2$ of Table 3 gives an overview of the main characteristics of the second wave of studies based on data from the United States (Burgess and Propper (1998), Zarkin et al. (1998), French et al. (2001), DeSimone (2002), Conti (2010)), Britain (MacDonald and Pudney (2000), Conti (2010)) and the Netherlands (Van Ours (2006), Van Ours (2007)). This wave of research, defined as those studies published from 1998 onwards, generally seek to improve on the earlier work in one or more of the following three main ways. First, they may seek to determine whether there is a dose-response relationship between drug use and labor market outcomes. Many argue that unlike heavy or chronic drug use, low or moderate drug use is unlikely to cause harm, and it is therefore important to distinguish between different intensities of use when examining the impact of drug use on labor market outcomes. Second, these studies often raise the issue of timing. If heavy drug use lowers productivity, is its effect immediate? Or is only persistent long term use harmful? Even if its effect is immediate, it may take time for an employer to notice and to take action. Consequently, any effects of heavy use may be more apparent in samples of older people. In order to assess the possibility that there are delayed or cumulative effects of drug use on labor market outcomes, data sources that include older individuals are typically used. There have also been efforts to separate out the effects of past from current drug use. The third issue addressed by some of the second wave of studies is the issue of the identification of the causal impact of drug use. Approaches to this issue include: using lifetime rather than current drug use as a way of minimizing the problem of reverse causality; using clinical definitions of drug abuse; looking more carefully at the economic and statistical merits of instruments; and using alternative econometric strategies that do not depend on exclusion restrictions for identification.

Taken at face value, second wave studies tend to find evidence that non-problematic use of drugs (light to moderate use, or the use of soft drugs) has no impact on labor supply, measured by employment or hours worked, but that problematic use (heavy use, or the use of hard drugs) does, although Burgess and Propper (1998); DeSimone (2002); Zarkin et al. (1998) and Van Ours (2006) provide counter-examples. Similarly, most of the second wave studies find that infrequent or non-problematic drug use has no impact on wages, whereas problematic use does have negative wage effects. Once again, there are also exceptions to this generalization, such as MacDonald and Pudney (2000). It is again worth noting that, even among the more rigorous of these studies, the interpretation of estimated effects as causal relies on untestable identifying assumptions. Accordingly, any conclusions drawn form them are subject to the same caveats and cautions discussed above.

Given the conflicted nature of the empirical findings and questions surrounding identification strategies, it is simply uncertain as to whether there are negative labor market consequences of drug use in general, and cannabis use in particular. Furthermore, it is unclear as to whether this literature should be interpreted as reflecting a lack of robust evidence of a negative health effect of drug use (possibly due to poor identification strategies), or as reflecting the presence of a productivity improving effect of drug use that is confounding the negative health effects.

6 Discussion and conclusions

Despite a substantial number of epidemiological studies and a growing number of econometric studies not much is known with any degree of certainty about the health effects of cannabis use. Researchers agree on the association between cannabis use and bad health. The issue is whether this association is causal, running from cannabis use to health, or whether there are joint determinants unaccounted for producing spurious correlation, or whether the causality runs in reverse, from poor health to cannabis use. The main issue for researchers is that the optimal set-up from a scientific point of view, a field experiment with randomization of cannabis use, is not possible for at least two reasons. First and foremost, individuals will know whether they received the "treatment" or not. Second, long term exposure to cannabis would be required and this would be rather unethical in the event that cannabis is harmful to one's health.

The lack of econometric research that focuses on the question of causality is surprising but likely to be related to the paucity of good data as a basis for the research. Cannabis use is not a static phenomenon. On the contrary, dynamics in use are very important. Within the population some individuals may start using cannabis but others will abstain. Among those who have started using cannabis there are individuals who will stop using and other individuals who will persist in use. By and large, in the population there are never users, experimental users and persistent users. Even within the group of persistent users there may be transitions from high intensity of use to low intensity of use and vice versa. To understand the dynamics of cannabis use, information is needed from the time that the individual was first confronted with the choice to use a particular drug. Ideally, this information would include how relevant circumstances change over time. Information that could be important includes the family situation, experiences at school, changing supply conditions, prices of drugs, etc. Unfortunately, this type of information is most often not available.

When assessing the health effects of cannabis use some caveats are important.

First, all health effects are established under a single policy regime, prohibition. The legal status of a drug may affect the relationship between drug use and health. Furthermore, by virtue of its legal status, is not easy to collect reliable data on cannabis use. A second caveat concerns the way illegal drugs are consumed. Smoking heroin for example is less dangerous than injecting heroin. Inhaling cannabis that is vaporized is less dangerous than smoking cannabis. A third caveat is that there have been important changes over time in cannabis. Specifically, the proportions in which the two main psycho-active components of cannabis, delta-9-tetrahydrocannabinol, which exaggerates psychotic effects, and cannabidiol which moderates psychotic effects, is believed to have changed in recent years. While the proportion of the former has increased, the proportion of later has decreased and the net health effects of these changes are uncertain.

The impact of long term heavy cannabis use on the development of diseases such as emphysema and cancer remains under debate, however only a small fraction of the population will engage in cannabis use to this degree. There is very little known about the impact of short-term use or long-term recreational use on health but the limited available evidence does not indicate large effects. There has been growing concern over the mental health effects of cannabis use. While the epidemiology literature is quite mixed in whether there exists a causal effect of cannabis use on mental health, the economics literature appears to produce a degree of consensus in finding that the impact of cannabis use for moderate users is small, but that intense use is likely to significantly reduce mental health and well-being, especially for those vulnerable to mental health problems. In terms of the indirect health effects of cannabis use, the literature has produced robust evidence that early cannabis use reduces educational attainment. However, there remains insufficient evidence on which to speculate on the labor market impact of using cannabis. Of course, these conclusions are subject to the caveats regarding identifying assumptions.

Notes

[1]The annual prevalence of use of other illegal drugs is substantial smaller; see for example Van Ours and Williams (2014) in their overview of the health effects of illegal drug use. According to United-Nations (2013) between 14 an 21 million people used cocaine at least once a year, while for ecstasy the number of past year users is estimated to be between 10 and 29 million. Information on drug use is usually based on self-reported data from population

surveys. Most empirical studies on the effects of cannabis use on health, education and labor market success are based on this type of data. There is some discussion on the reliability of this information. Pudney (2004) suggests that misreporting of drug use may not be too serious. In particular misreporting about cannabis use is less of a problem since it is a more socially acceptable drug.

[2]For example, see Caulkins et al. (2012) for an excellent discussion summarizing cannabis legalization design issues inspired by the recent debate in California. In the debate on legalization of cannabis the demand relationship between cannabis and alcohol is important. If the two are substitutes cannabis legalization will lead to an increased use of cannabis but a drop in the use of alcohol. Recent studies suggest that at least for young adults cannabis and alcohol are substitutes; see: DiNardo and Lemieux (2001), Crost and Guerrero (2012) and Anderson et al. (2013).

[3] It was recognized by the WHO in 1993 when the tenth revision of the International Classification of Diseases was released and by the American Psychiatric Association in 1994 when the Diagnostic and Statistical Manual of Mental Disorders (4th Edition) was released.

[4]See Johns (2001) for a full discussion of this issue.

[5]Epidemiology has also contributed a number of papers investigating the association between of cannabis use in pregnancy and birth outcomes that offer mixed findings. See for example Hayatbakhsh et al. (2012). None of these papers deal with the critical issue that using cannabis while pregnant is a choice that is likely determined by unobserved factors that also determine birth outcomes.

[6]This measurement error arises in one of two ways, depending on the method used to determine intoxication. If cannabis intoxication is measured using THC concentration in blood serum, the issue is classifying drivers who were impaired by cannabis at the time of the crash as not impaired. This occurs due to the delay that occurs between the time that the accident occurs and the time that drivers blood is sampled combined with a lack of knowledge about the speed at which cannabis is metabolized. As a consequence, it is almost impossible to extrapolate backwards from the concentration of THC at the time blood is drawn to be tested to THC levels at the time the accident occurred. The second source of measurement error arises in studies that use the metabolite of THC, carboxy-THC, to establish cannabis use among crashed drivers (Ramaekers et al. (2004)). Because this metabolite can be detected in urine or blood days after cannabis has been used and long after cannabis intoxication has ceased, studies using this metabolite will mistakenly classify some non-impaired drivers as impaired. Either of these two types of measurement error will lead to an underestimate the impact of recent cannabis on vehicular accidents.

[7] These range from 13.2 percent when they consider drivers with a blood alcohol limit greater than zero, to 15.5 percent when they consider fatalities resulting from a driver with a BAC of 0.10 or greater.

[8]Cannabis uptake and quitting are assumed to have a multivariate mixed proportional hazard structure and identication of unobserved heterogeneity in the health equations relies on their linear functional form and the assumption that their idiosyncratic errors are normally distributed.

[9]Dependence is an important mental health effect of cannabis use that has been omitted from this review. As discussed in Hall (2006), around 1 in 10 cannabis users meet the criteria for dependence. The risk of dependence is much higher amongst daily users and those who start at an early age.

[10]Fergusson et al. (2002) is an exception in that they also control for unobserved heterogeneity using fixed effects models.

[11] Early studies that assume exogeneity of cannabis use are Yamada et al. (1996) and Bray et al. (2000) who both find significant negative effects of educational attainment.

[12]In tests not reported, the authors fail to reject the exogeneity of chronic and non-chronic cannabis use in their model for high-school drop-out.

[13]The set of instruments used in Chatterji (2006) include state level cannabis policy variables along with 2 school level variables related to the principal's perceptions and policies regarding drug use at the school the individual attended for grade 8. Register et al. (2001) and Roebuck et al. (2004) use religiosity to instrument cannabis use.

[14]Their results suggest that leaving formal education has no (statistically significant) impact on the uptake of cannabis by males, but it does have a small positive impact on the uptake by females. Nonetheless, the estimated effect of initiation into cannabis on leaving formal education is not sensitive to accounting for reverse causality.

[15]We note that the authors show that when peer effects related to cannabis use are accounted for, own cannabis use no longer has a significant effect on high-school drop-out. This is interpreted as suggesting that rather than having a causal effect, cannabis use is correlated with unobserved common confounders that lead to drop-out. An alternative interpretation is that peer effects is the mechanism via which cannabis use effects high-school graduation.

[16]For example, non-wage income, frequency of religious attendance in 1979, the number of delinquent acts in 1980 and current number of dependents are used as instrument for cannabis use in the wage equations estimated by Kaestner (1991); Register and Williams (1992) instrument cannabis use with mothers education, fathers education, being raised in a Baptist or Methodist household, attending religious services at least weekly, divorced in the past

year, and living in a central city; and Gill and Michaels (1992) instrument substance use with the frequency of going to bars in the month before being interviewed, an indicator for kept drinking after promising yourself not to, income from illegal activities in 1980, and an indicator for being charged with breaking the law in 1980.

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Table 1: Intensity of cannabis use; various countries (%)

Country	Survey year	Ever use	Last year use	Last month use	Daily use (last month)
Australia	2007	35.4	10.3	5.8	–[a]
Austria	2008	14.2	3.5	1.7	0.3
Belgium	2008	14.3	5.1	3.1	0.9
Czech Republic	2008	34.2	15.2	8.5	0.8
Denmark	2010	32.5	5.4	2.3	0.5
England and Wales	2012	31.0	6.9	4.1	0.5
Finland	2010	18.3	4.6	1.4	0.2
France	2010	32.1	8.4	4.6	1.5
Germany	2009	25.6	4.8	2.4	0.4
Hungary	2007	8.5	2.3	1.2	0.3
Italy	2012	21.7	3.5	1.5	0.3
Netherlands	2005	22.6	5.4	3.3	0.8
Norway	2009	14.6	3.8	1.6	0.3
Poland	2010	17.5	9.6	5.4	0.4
Portugal	2007	11.7	3.6	2.4	1.1
Slovakia	2010	10.5	3.6	1.4	0.0
Spain	2011	27.4	9.6	7.0	2.5
US	2010	42.0	11.5	6.9	2.8

[a]: Last week use: 3.8%.

Note: Population age 15-64 except Australia 12 and older; Denmark 16-64; Hungary 18-64; Italy 18-64; US 12 and older. Last month daily use = Prevalence of daily or almost daily use (20 days or more in the last 30 days).

Sources: European countries – EMCDDA (European Monitoring Center for Drugs and Drug Addiction); Australia – AIHW (Australian Institute of Health and Welfare); US – SAMHSA (Substance Abuse and Mental Health Services Administration).

Table 2: Overview of medical and epidemiological overview studies on the effect of cannabis use on mental health

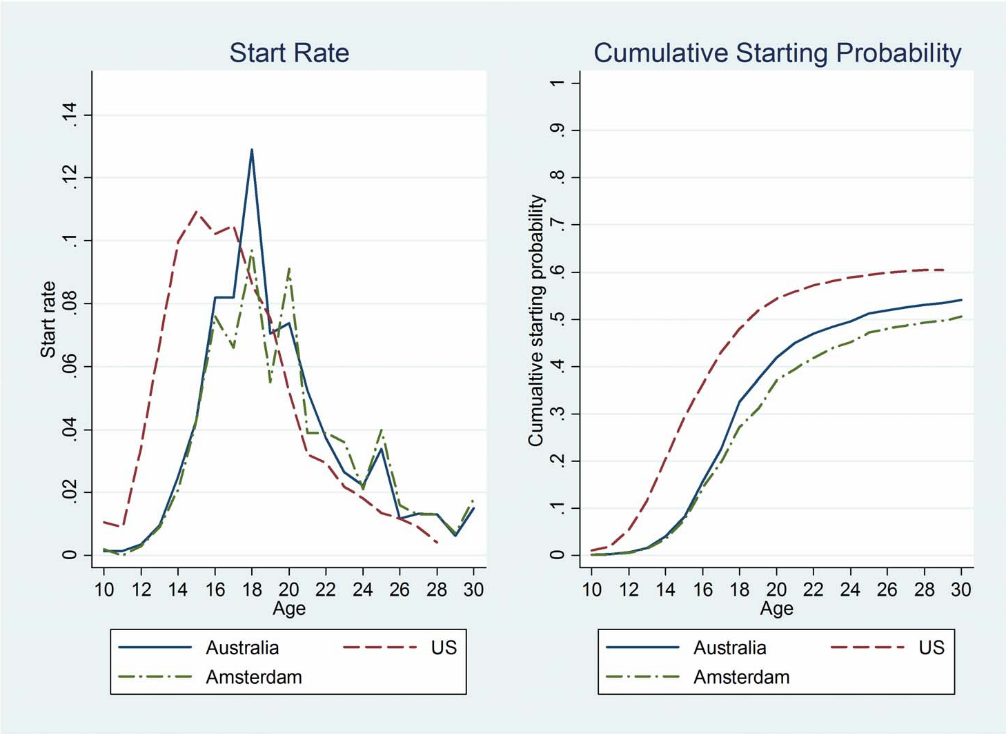
Reference	Health variable	Effect of cannabis use
Degenhardt et al. (2003)	Depression	Modest association between problematic cannabis use and later depression
Arseneault et al. (2004)	Psychosis	Neither necessary nor a sufficient condition for the development of psychosis
Kalant (2004)	Psychiatric problems	More evidence for causality than for reverse causality
Macleod et al. (2004)	Psychosocial harm	Evidence of association but causal nature is far from clear
Henquet et al. (2005)	Schizophrenia	Causal but not very large effect; mechanism is unclear
Semple et al. (2005)	Psychosis	Association but unclear whether this is causality or reverse causality
Hall (2006)	Psychosis	Association but whether this is causal remains controversial
Moore et al. (2007)	Psychosis	Association but influence from confounding factors cannot be ruled out
Hall and Degenhardt (2009)	Depression	Epidemiological research on association is mixed
McLaren et al. (2010)	Psychosis	No causal conclusions can be based on current studies
Werb et al. (2010)	Psychosis	Insufficient evidence to conclude that there is a causal effect

Table 3: Causal effects of cannabis use on health, education and labor market success; econometric studies

Reference	Country	Data from	Illegal drugs	Methodology	Effects of illegal drug use
a. Direct health effects					
Williams and Skeels (2006)	Australia	2001 & 2004	Cannabis	Instr. variables	Negative health effect
Van Ours and Williams (2011)	Australia	2004	Cannabis	Timing of events	Worse mental health
Van Ours and Williams (2012)	Netherlands	1994	Cannabis	Timing of events	Worse mental and for men worse physical health
Van Ours et al. (2013)	New Zealand	1977-2007	Cannabis	Timing of events	More suicidal ideation (men)
b. Effects on education					
Register et al. (2001)	United States	1992	Cannabis &hard drugs	Instr. variables	Negative impact
Roebuck et al. (2004)	United States	1997-1998	Cannabis	Exogeneity test	Chronic cannabis use negative impact
Chatterji (2006)	United States	2000	Cannabis & cocaine	Instr. variables	Negative impact
Van Ours and Williams (2009)	Australia	2001	Cannabis	Timing of events	Negative impact for early starters
McCaffrey et al. (2010)	United States	1997-2004	Cannabis	Propensity score matching	No effect
c. Effects on labor market success					
c1. First wave					
Kaestner (1991)	United States	1984	Cannabis-cocaine	Instr. variables	Higher wages
Gill and Michaels (1992)	United States	1984	Cannabis-cocaine	Instr. variables	Higher wages
Register and Williams (1992)	United States	1984	Cannabis	Instr. variables	Higher wages
Kaestner (1994a)	United States	1984 & 1988	Cannabis-cocaine	Instr. variables	No effect hours of work
Kaestner (1994b)	United States	1984 & 1988	Cannabis-cocaine	Instr. variables	No effect on wages
c2. Second wave					
Burgess and Propper (1998)	United States	1979-1992	Soft & hard drugs	Instr. variables	Hard drugs negative employment effects
Zarkin et al. (1998)	United States	1991 & 1992	Illegal drugs	Instr. variables	Little effect on hours of work
MacDonald and Pudney (2000)	Britain	1994 & 1996	Soft & hard drugs	Instr. variables	Hard drugs negative employment effects
French et al. (2001)	United States	1997	Illegal drugs	Instr. variables	Chronic drug use negative employment effects
DeSimone (2002)	United States	1984 & 1988	Cannabis-cocaine	Instr. variables	Negative employment effects for males
Van Ours (2006)	Netherlands	1994-1997-2001	Cannabis-cocaine	Timing of events	No employment effects
Van Ours (2007)	Netherlands	1994-1997-2001	Cannabis	Timing of events	Negative wage effects
Conti (2010)	Britain	1970-2004	Cannabis	Structural factor model	No wage effects
	United States	1980-1998			No wage effects

Figure 1: Dynamics in cannabis use in Amsterdam

a. Starting rates (left) and cumulative starting probability (right) by age



b. Quit rates (left) and cumulative quit probabilities (right) by duration of use in years